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ABSTRACT

Scales and otoliths of the red porgy, *Pagrus pagrus*, sampled from the North Carolina and South Carolina headboat fishery were examined to determine if they could be used for aging the species. Both structures were satisfactory, but because of regeneration and false annuli, only 54% of the fish examined could be aged by scales. Ages could be determined from a larger percentage of the otoliths, but preparation and examination was time-consuming. Maximum age of fish collected was XV; maximum total length was 694 mm. Growth occurred from about mid-March to November. Back-calculated mean lengths ranged from 176 mm at end of year 1 to 640 mm at the end of year 15. Total mortality estimates, based on catch curves from over 13,000 fish, ranged from 32 to 55%. The length-weight relationship is described by the equation $W = 0.00002524L^{2.8939}$, where W is weight in grams, and L is total length in millimeters.

The red porgy, *Pagrus pagrus*, is a bottom-dwelling marine fish associated with a variety of temperate to subtropical habitats in the eastern and western Atlantic. In the western Atlantic it commonly occurs in waters from 10 to 100 fathoms from North Carolina to Mexico and from Venezuela to Argentina. In addition to being harvested commercially by hook and line, it is caught in large numbers by recreational fishermen off the southeastern United States. In North Carolina and South Carolina over 700,000 fish weighing approximately 771 metric tons were landed from 1972 to 1974 (Sekavec and Huntsman 1973; Huntsman 1976).

The red porgy of the eastern Atlantic is mentioned in numerous papers, but the red porgy of the western Atlantic is discussed in only three. Ginsburg (1952) conducted a taxonomic study; Dias et al. (1972) examined the relationship between standard, fork, and total length, and length to weight; and Ciechomski and Weiss (1973) discussed eggs and larvae from Argentine waters.

In 1972 the National Marine Fisheries Service, Atlantic Estuarine Fisheries Center, Beaufort, North Carolina, initiated life history, creel census, and tagging studies of demersal fishes, including the red porgy, occurring on the outer Continental Shelf of the Carolinas. The overall objective of the study was to collect information necessary for understanding the demersal fish resources of the southeastern United States. A specific objective was to investigate methods of aging the various species that are important to the recreational fishery.

In this paper we report on studies to determine if the red porgy can be aged by the number of rings appearing on scales and on otoliths. We also describe the length-weight relationship, estimate absolute, calculated, and theoretical growth, and estimate total mortality rates for the different fishing areas.

METHODS

From 1972 to 1974 we examined 13,120 red porgy from three geographic locations of the North Carolina and South Carolina headboat[1] hook and line fishery: Cape Lookout (area 1), Cape Fear (area 2), and Cape Romain (area 3) (Fig. 1). An additional 200 fish taken in trawls off South Carolina were obtained from the South Carolina Marine Resources Commission. We recorded total length in millimeters and weight in grams for fish less than 250 mm. For fish over 250 mm the weight was recorded to the nearest tenth of a pound and later converted to grams. Scales were taken from beneath the tip of the posteriorly extended pectoral fin, soaked in a one-tenth aqueous solution of phenol, and rubbed between the fingers to remove chromatophores and integument. Six scales per fish were mounted dry between two glass slides and viewed on an Eberbach projector[2] at 40× magnification.

[1] A boat for hire which charges on a per person basis.

[2] Reference to trade name does not imply endorsement by the National Marine Fisheries Service, NOAA.

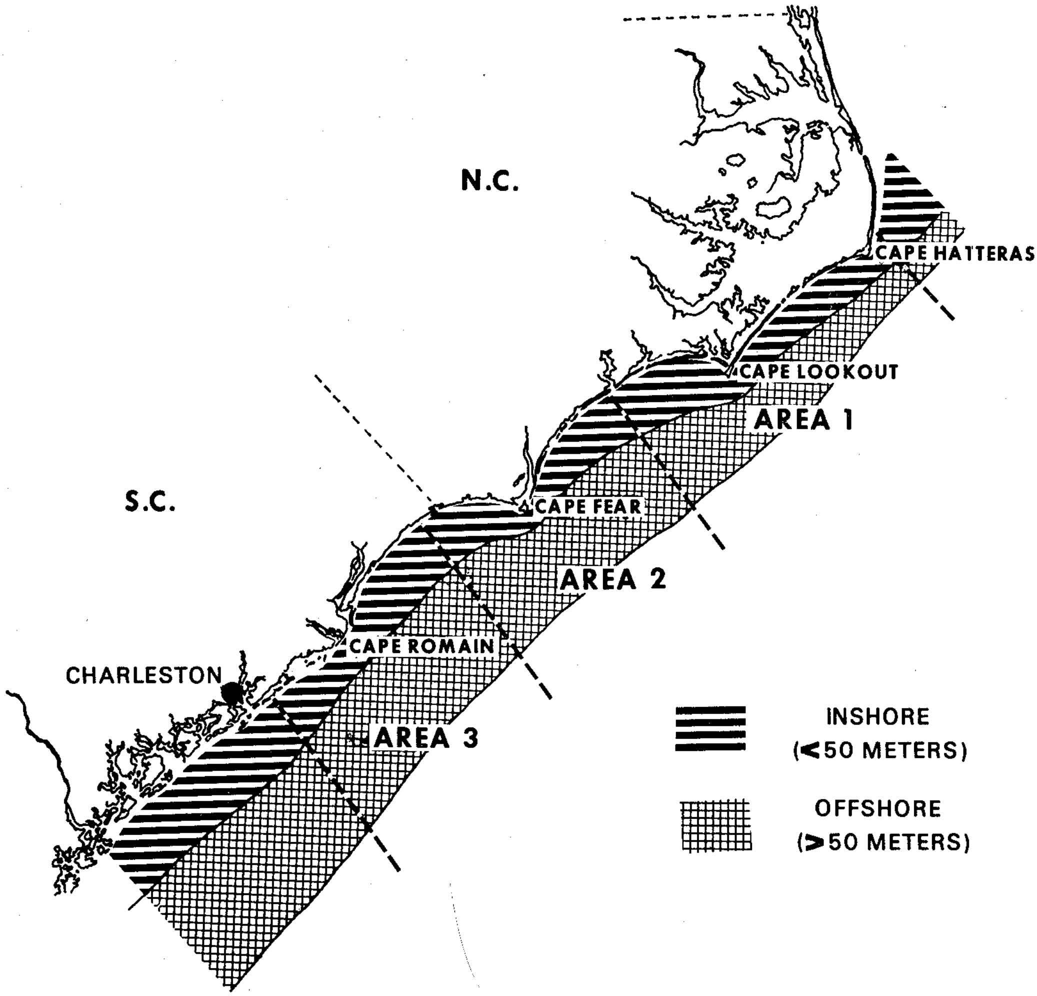

FIGURE 1.—*Location of the three major sampling areas, 1972–1974.*

Measurements were along the anterior radius. Each scale was read twice.

We removed otoliths (sagittae) from 222 fish. The otoliths were stored and examined (whole, by reflected light) in glycerol.

RESULTS

Of the total 3,278 ctenoid scales examined, we were able to discern and measure rings on approximately 54%. The percentage of illegible scales generally increased as fish length increased. Scales were illegible because of regeneration, indistinct or broken rings, or rings too close together to separate.

Each red porgy otolith contains opaque and hyaline bands. The opaque zones which were evenly spaced and contiguous, were interpreted as having been formed during the growing season, and therefore were counted as growth rings.

Validity of Rings as Annuli

By calculating the mean distance from the last ring to the scale edge of 2- and 3-ring fish collected from May to December, we were able to determine the approximate time of year when the rings were formed. Growth had already resumed when the first collections were

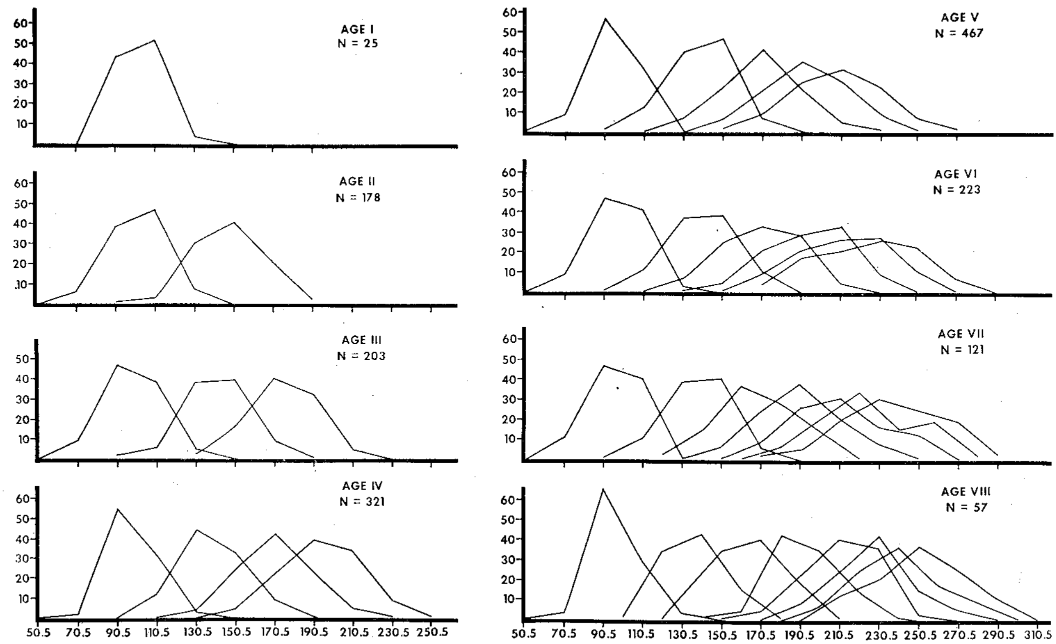

FIGURE 2.—*Frequency distribution (Y-axis, %) of measurements of scale lengths to each annulus (X-axis, mm × 40) for red porgy age I–VIII.*

taken in early May. The mean (magnified) distance from ring to edge for 2-ring fish increased from 13.9 mm in May to 24.9 mm in October, and did not change from October to December. Since we had no collections from December to May, we could not determine exactly when during that period growth resumed and the annulus was formed. Judging from the amount of growth that was evident on scales of fish collected in May, we concluded that the annulus was formed sometime in March or April. The period of no growth, November to March, coincided with the time of lowest bottom water temperature and with gonadal development (Manooch 1976a).

Frequency distributions of focus-to-ring distances (Fig. 2) show an occurrence of one mode for each ring, a consistant pattern of the modes from year to year, an increase in the amount of overlap for each additional ring, and a progressive decrease in the distance between the modes.

Although we read otoliths from 222 fish, we had both scales and otoliths from only 50 individuals. The number of rings on both scales and otoliths agreed for 43 out of the 50 (86%). In the seven instances of disagreement the number of rings on otoliths was always one greater than the number on scales, possibly due to the otolith kernal being counted as a growth ring.

The mean length of fish progressively increased as the number of scale or otolith rings increased (Table 1). For instance, if aged by scales, age-I fish averaged 238 mm, age-V fish 419 mm, and age-X fish 543 mm; if aged by otoliths, age-I fish averaged 228 mm, age-V fish 402 mm, and age-X fish averaged 534 mm (Table 3).

The evidence, we believe, indicates that the rings on scales and otoliths are true annuli. But since over 46% of the scales were illegible, we think that unless scales from a large number of fish are available, otoliths should be used in aging. Red porgy reach sexual maturity at age IV (Manooch 1976a); therefore, spawning can be eliminated as a cause of ring formation at least for the early years.

Growth

Young-of-year red porgy usually were not taken in the fishery, since the hooks used were

TABLE 1.—*Comparisons of red porgy lengths by scale (*n = *1,777) and otolith (*n = *222) ages.*

	Scales			Otoliths		
Age group	Number	Mean total length mm	Standard deviation	Number	Mean total length mm	Standard deviation
I	25	238	22.3	2	229	37.5
II	180	290	24.5	17	288	19.1
III	203	342	24.9	26	331	21.2
IV	323	382	37.9	29	374	22.5
V	501	419	27.1	50	402	21.5
VI	235	451	21.2	31	425	27.3
VII	138	483	23.7	27	453	20.1
VIII	68	505	21.0	14	474	23.1
IX	38	527	29.4	18	496	23.4
X	35	543	24.1	4	534	22.2
XI	19	558	23.7	4	557	52.5
XII	10	604	13.5	0		
XIII	1	595		0		
XIV	0			0		
XV	1	694		0		

too large to catch them. However, we did obtain 43 from the South Carolina Marine Resources Department that had been collected by trawl off Charleston, South Carolina, in April, 1974, and 22 that had been collected in November, 1974. Fish in the November collection averaged 43 grams heavier and 92 mm longer than those in the April sample.

Observed lengths for fish of the same age (for those age I and greater) were similar for the three areas sampled. Mean annual increment for the three areas for ages I–XII were: 32 mm, 36 mm, and 34 mm, respectively. Mean lengths for age I fish were almost identical for the three areas: 236 mm, 238 mm, and 236 mm. After the first year, fish from Cape Lookout generally attained slightly greater mean lengths per age than those from the other two areas. Since little difference in length at a given age was noted between areas, the data were combined.

Growth of fish aged by scale annuli (Table 1) was relatively fast for about the first seven years and then became less rapid. Annual increments for the first seven years were: I–II, 52.4 mm; II–III, 51.4 mm; III–IV, 40.9 mm; IV–V, 36.3 mm; V–VI, 32.5 mm; and VI–VII, 31.7 mm. Not enough fish were sampled to estimate the annual increments after year 12.

Lengths by age for area and year of collection were back-calculated from scale radius-fish lengths regressions. Since little difference was noted between years or areas for observed length at age the data were combined (Table 2).

The X-axis intercept derived from the scale radius-fish length regression has been the subject of much debate. A 0-intercept would indicate simultaneous scale growth with fish body growth, a negative intercept would indicate scale formation before the fish had body length, and a positive intercept would mean

TABLE 2.—*Back-calculated total lengths of 1,685 red porgy aged by scales.*

		Mean calculated total length at end of year, mm														
Observed age	Number of fish	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
I	25	185														
II	178	184	267													
III	203	177	259	318												
IV	321	174	251	311	351											
V	467	172	250	308	351	380										
VI	223	176	254	309	352	385	408									
VII	121	182	261	318	363	398	425	447								
VIII	57	174	250	306	350	383	412	442	452							
IX	33	172	254	313	356	388	413	435	452	466						
X	32	170	257	315	359	390	415	437	456	470	484					
XI	16	174	265	328	369	401	425	445	461	480	493	504				
XII	7	176	257	309	359	397	419	446	471	490	504	523	534			
XIII	1	159	244	307	359	405	427	450	464	477	493	503	520	541		
XIV																
XV	1	177	254	316	368	412	438	463	484	502	526	552	572	599	619	640
Weighted mean		176	258	311	353	385	414	443	455	472	490	511	537	570	619	640
Increments			82	53	42	32	29	29	12	17	18	21	26	33	49	21

that the fish had body length before scales were formed. Theoretically, the latter is correct. We checked juveniles which ranged in length from 18 to 60 mm and found each to possess scales under the pectoral fin. Obviously the fish at scale formation were less than 18 mm.

Regression equations were derived by plotting projected (40×) scale length on total fish length by area of collection. Since a majority of the projected scale radius measurements were between 175–225 mm due to fishing gear selectivity, we subsampled scale radius measurements after grouping them into 25-mm size intervals. The intercept values for fish from areas 1 and 3 were unrealistically high and the data, when plotted, were extremely scattered around the regression line. Plotted data for Cape Lookout, however, were in proximity to the regression line and the intercept of –3.479 was close to 0. For these reasons and because field personnel in the Cape Lookout area had followed instructions closely for taking scale samples (personnel in the other areas had not), we used the regression equation derived from Cape Lookout data to predict fish length at each annulus.

The formula was

$$TL = -3.479 + 1.838\,SR,$$

where TL = total length and SR = projected scale radius or scale length; $r = 0.92$; $n = 191$.

We substituted the means of the distances from the focus to each annulus for SR in the above equation, calculated the mean fish length at the time of each annulus, and then calculated mean growth increment for each age group (Table 2).

Theoretical growth parameters were obtained from back-calculated data and used to derive the von Bertalanffy growth equation: $l_t = L_\infty (1 - e^{-K(t-t_0)})$ (Bertalanffy 1938); where l_t = total length at age t, L_∞ = maximum attainable size, K = growth coefficient, and t_0 = hypothetical age at which the fish would have been zero length if it had always grown in the manner described by the equation. Following Ricker (1975, p. 225), $L_\infty = 763$ mm, $K = 0.096$, and $t_0 = -1.88$, yielding $l_t = 763\,(1 - e^{-0.096(t+1.88)})$. The L_∞, 763 mm, is not unrealistic since a red porgy 741 mm TL was sampled by task personnel off Charleston, South Carolina in 1975.

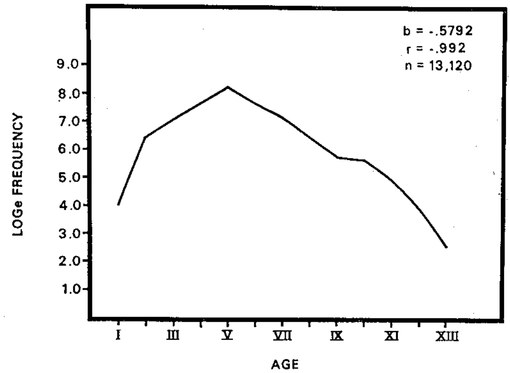

FIGURE 3.—*Catch curve for 13,120 red porgy sampled from the headboat fishery off North Carolina and South Carolina, 1972 to 1974, where* b, *the slope of the right descending limb of the curve, equals the instantaneous rate of mortality.*

Mortality Estimates

Red porgy are fully vulnerable to the hook and line fishery, the only method of harvesting this species off the Carolinas, by age V. Annual total mortality estimates from the catch curves, therefore, were based on fish age V and older. If the $\log_e$ of the age frequency in the catch is plotted on age, the slope of the descending right limb is equal to the instantaneous total mortality rate (Fig. 3).

We grouped fish of known age by 25-mm length intervals, calculated the percentage of fish of each age in each group, and used these percentages to estimate the number of fish of each age for each 25-mm length group of the 13,120 unaged fish. From the resulting catch curves, we estimated the annual total mortality rate in each area by the methods of Heinke (1913), Jackson (1939), Robson and Chapman (1961), Rounsefell and Everhart (1953), and Beverton and Holt (1957).

Mean total annual mortality estimates ranged from 32 to 55%, depending on the area and method of estimating (Table 3). Cape Lookout generally had the lowest annual mortality rates while Cape Fear had the highest rates. The highest estimates for all areas combined were from the 1972 catch curves, the lowest from the 1973 catch curves. Although

TABLE 3.—*Total annual mortality estimates for red porgy from North Carolina and South Carolina, 1972 to 1974.*

Year	Area	Sample size (V-oldest)	Number of age classes	Method: Jackson (1939)	Robson and Chapman (1961)	Heinke (1913)	Beverton and Holt (1957)	Rounsefell and Everhart (1953)	Mean mortality
1972	1	474	7	0.32	0.36	0.32	0.29		0.32
	2	779	7	0.54	0.55	0.54	0.55		0.55
	3	1,621	8	0.48	0.52	0.48	0.55		0.52
	Combined	2,883	9	0.47	0.49	0.47	0.52		0.49
1973	1	833	7	0.38	0.42	0.38	0.39		0.40
	2	1,229	8	0.35	0.38	0.35	0.37		0.37
	3	1,888	8	0.44	0.46	0.44	0.43		0.44
	Combined	4,044	9	0.40	0.42	0.40	0.47		0.43
1974	1	259	8	0.35	0.36	0.35	0.40		0.37
	2	600	7	0.48	0.47	0.48	0.43		0.46
	3	1,218	9	0.44	0.44	0.44	0.42		0.43
	Combined	2,077	9	0.44	0.43	0.44	0.44		0.44
1972–1974	Combined	9,006	9	0.43	0.44	0.43	0.44	0.47	0.44

there was little difference in values, we consider the regression method of Beverton and Holt (1957) to be the best estimator, since it utilizes geometric rather than arithmetic means.

We do not believe that the recreational and commercial fisheries have greatly contributed to total mortality. Returns of tagged fish indicate a fishing mortality of only 1 to 2%, although the rate is probably underestimated because of tag losses (Manooch 1975).

One point not in the catch curve is that after age XI there is a drastic decrease in relative numbers of fish caught. Since gear size obviously does not select against these individuals it seems probable that a great majority die naturally after age XI.

Length-Weight Relationships

The relation of weight (g) to total length (mm) for 544 red porgy from all areas is described by the equation: Weight = 0.00002524 Length$^{2.8939}$; $r = 0.99$. For each area the equations are similar. Equations were also similar for each sex, although males were slightly heavier than females.

DISCUSSION

Annular rings on scales and otoliths of fish from tropical and subtropical waters are often difficult to detect and interpret, since there is little annual fluctuation in water temperatures and thus little seasonal variation in growth. Although inshore collection sites experience rather drastic changes in bottom water temperatures (Grimes 1976), temperatures offshore, in the shelf break area, vary from 4 to 5 C between summer and winter (Newton et al. 1971). With such small temperature differences offshore, one would expect scales to have no annuli, or such a profusion of growth checks that identifying the true annuli would be difficult. Chevey (1933), however, has shown that even small temperature differences may suppress growth long enough to cause annuli to form, and Menon (1950) and Iles (1974) have suggested that physiological rhythms associated with spawning may also be important in the retardation of somatic growth.

Ages could be determined from either scales or otoliths, but scales were easier to obtain and measurements could be recorded quickly. There was, however, much regeneration of scales and a high frequency of false annuli. We found regenerated scales in almost all of the individual scale samples, but fewest in those samples taken beneath the pectoral fin. Paul (1968) found this area to have the least variation in scale shape for the New Zealand sparid, *Chrysophrys auratus*, and Grimes (1976) found fewer regenerated scales beneath the pectoral fin of the vermilion snapper, *Rhomboplites aurorubens*. Otoliths could be read easily, but they required a lot of labor to prepare, could not be projected, and required a dissecting microscope and a calibrated ocular micrometer to be measured.

The red porgy is rather long-lived and displays a slow, steady rate of growth, reflecting not only its genetic capabilities but also the type of environment in which it occurs. Theoretical growth as described by the von Bertalanffy equation predicts a maximum total length of 763 mm and a growth coefficient, K, of 0.096. The growth coefficient compared with three sympatric species indicates a faster growth rate than the black sea bass, *Centropristis stirata*, $K = 0.088$ (Cupka et al. 1973), a slower rate of growth than the vermilion snapper, $K = 0.198$ (Grimes 1976), and a similar rate of growth to the white grunt, *Haemulon plumieri*, $K = 0.108$ (Manooch 1976b). By comparison, pelagic species have much more rapid rates of growth; king mackerel, *Scomberomorus cavalla*, $K = 0.35$ (Beaumariage 1973); yellowfin tuna, *Thunnus albacares*, $K = 0.42$ (Le Guen and Sakagawa 1973); and Atlantic menhaden, *Brevoortia tyrannus*, $K = 0.391$ (Schaaf and Huntsman 1972). The three areas from which red porgy were collected are similar, and show little temperature and salinity changes throughout the year. Red porgy, which are relatively sedentary and live in a stable environment, therefore are able to expend more energy on growth than species which migrate extensively and must compensate for physiological stresses produced by salinity and temperature changes or seasonal availability of food.

Competition for food and space, two factors which usually have pronounced effect on growth, do not seem as critical for red porgy as some fishes. We found red porgy to be opportunistic browsers that feed on a tremendous variety of invertebrates in addition to small fish. They are not dependent on a few species of organisms, but utilize whatever is available (Manooch 1977). While there is great interspecific competition for food among many species (lutjanids, pomadasyids, serranids) the crustacean, echinoderm, and molluscan base of the food chain appears to be extensive with respect to diversity and biomass.

Differences in length-weight regressions by area of collection and sex were slight. This would be expected considering the uniformity of environments of the areas sampled, and the approximately equal mass of female and male gonadal tissue (Manooch 1976a). The prediction equation for both sexes combined, representing all areas was:

$$W = 0.00002524\ L^{2.8939} \text{ or}$$

$$\text{Log}_{10}\ W = -4.59785 + 2.89390\ \text{Log}_{10}\ TL.$$

This equation compares favorably with the one obtained by Dias et al. (1972) who derived $\text{Log}_{10}\ W = -4.15693 + 2.7385\ \text{Log}_{10}\ TL$.

We do not believe that fishing mortality will have a pronounced effect on total mortality in the near future because: (1) gear selectivity excludes smaller and younger individuals; (2) access to the resource is limited since large, expensive boats are required to travel the long distances to fishing grounds, fishermen must often cope with inclement weather and unusual currents, and available gear cannot catch red porgy in deepest waters where they occur (>100 fms); (3) only minimal effort is exerted during the spawning period in late winter and early spring; and (4) overharvesting a widely distributed, well-adapted demersal species such as the red porgy by hook and line is highly improbable. Small geographically definable areas such as wrecks, rocks, or coral patches, however, may be overexploited and temporarily depleted. Yearly mortality estimates correlated with catch and effort data are needed to better describe the effect of the fishery on the red porgy population of the Carolinas.

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